HOW WE LEARN

A SHORT PRIMER OF SCIENTIFIC METHOD FOR BOYS

W. H. S. JONES

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A SHORT PRIMER OF SCIENTIFIC METHOD FOR BOYS

BY

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TO THE MEMORY

OF

S. S. F. F.

PREFACE

THIS little book is intended for the use of scholars of about sixteen, who for some terms at least have been trained to work out exercises in induction of the kind described and illustrated in the pamphlet *Scientific Method in Schools.* It sums up and systematizes, and to a certain extent develops, what they have been learning incidentally and partially. But it contains the very minimum that a pupil of sixteen should know, and it is suggested that the teacher would do well, before setting a section to be studied and learned at home, first to give an oral lesson expanding and illustrating the points treated in that section. The exercises at the end are intended to serve as written home work.

I hope that nobody will be offended at my intentional medley of trivial and important, of commonplace decisions and momentous discoveries. Such mixtures should not appear incongruous to anyone who remembers that "the method of discovery" is essentially one. My main object has been to impress upon the learner the unity of knowledge.

The teacher may find it useful if I append here a short list of problems that can be worked out by teacher and class together during the preparatory years before this primer is studied. The main characteristic of this work should be scientific thoroughness,

and the way of conducting it is described at some length in the pamphlet mentioned above. Some of these problems can be worked out by brighter and older pupils without help, but the teacher ought to be careful not to encourage unscientific habits by setting tasks above the powers of the class.

Exercises in Induction for Pupils between the ages of 13 and 16.

(1) Definitions of ordinary terms; e.g., *stupidity, hurry, piety, food, despair, sultriness, remorse, rapacity, statesman, quibble, pilgrim, drug, distress, instrument, hoard, harangue.*

(2) Grammar rules of various languages; e.g., the use of *which* and *who* in modern English; the difference between *le* and *lui* in French; the rules for the agreement of the relative in Latin; the use of the subjunctive in Latin to express indirect command; the rules for the agreement of the participle in French; the use of the supine in Latin.

(3) Historical commonplaces, e.g., the value of sea power; the value of strong government, even if tyrannical; the economic factor as a cause of wars; the dangers of absolute monarchy; oratory as a force in history; the factors most favourable to the growth of democracy.

(4) Mountain barriers as a protection from enemies; the origins of lakes; why towns have dwindled or disappeared; the effects of rivers upon the history of those dwelling in their basins; "the rule of the isthmus" in ancient times; the influence of large deserts upon surrounding countries.

(5) The law of levers; the law of pulleys; to find the centre of gravity of a disc, cube, etc.; the scientific meaning of "burning"; heat and expansion; elements combine in fixed proportions by weight (a working hypothesis formed from a few illustrations of the law); the effect of darkness upon plants.

(6) The marks generally left upon a man by his trade or profession (cobbler, farmer, fisherman, engineer, etc.); how to detect a smoker, a consumptive man, a short-sighted man, a man with a weak heart; the chief symptoms of common ailments.

I must thank Mr W. E. Johnson, Fellow of King's College, Professor R. L. Archer and Mr F. W. Westaway, for their great kindness in reading the proofs and correcting many errors and ambiguities.

W. H. S. J.

September 1916.

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CHAPTER I

INTRODUCTORY

Knowledge and Sensation.

What is Truth? What is Knowledge? Philosophers and scientists have discussed these questions for well over two thousand years, but complete answers seem as remote as ever. There has, however, been great progress, particularly during the last three hundred years. The problems are not solved, but we see our way better, and realize that we are on the right road to the solution, even though it prove ultimately to be unattainable. It is with the certainties, the admitted facts, that this little book will deal. (I wish to point out how each one of us can make his thoughts more accurate, and so express them that they may be accurately communicated to others.)

Pause for a moment and try to examine the nature of your thoughts, the contents of your consciousness, the way in which your mind acts upon the sensations presented to it.

In your waking hours a continuous stream of impressions intrudes itself upon you, impressions of shape, colour, smell, taste, touch, sound—everything in fact

that is conveyed by the five senses—the meaning of which, in proportion to the activity of your brain, you try to make clear to yourself. If you are sleepy, inattentive or ill, the impressions are often unobserved. The remark is constantly heard, "I did not notice that." But for the most part your mind is acting as an interpreter, explaining and arranging your sensations. You say to yourself:—

> That is a horse.
> The rain falls fast.
> The church is round.
> A bell is ringing.

These and similar statements are all interpretations of sense-impressions.

But the powers of the mind are not limited to present sensations and their interpretation. It can store up experience, a power we call *memory*, and so pass judgment on the past; it can also look forward and prophesy about the future.

> There was a frost last week.
> X. made fifty runs this afternoon.
> Julius Caesar was a great Roman.
> We shall go to London to-morrow.
> There will be a shower soon.

A close examination reveals that the powers of the mind are conditioned by its past experience, in the light of which it works. This experience may be its own. It may, however, be the experience of other minds, passed on by one of the means we possess of transmitting thought. The character of Julius Caesar, for example, is known to us because we have accounts of him in writing, which preserve for us the thoughts of Caesar's contemporaries.

But even the simplest acts of thought about present sense-impressions imply experience. Let us take the sentence:—

That is an orange.

What are our sense-impressions? We see something yellow, that looks round. If that were all we might be uncertain whether it is an orange or a yellow ball. But if we handle the yellow thing we are enabled to come to a correct decision. Experience comes to our aid and tells us that balls do not "feel" quite so. Furthermore, the mere use of language, without which we cannot think to any great extent, implies experience. When I read, either to myself or aloud, the word *horse*, I immediately associate the sound with a kind of composite photograph in my mind which has been formed by a long succession of past sense-impressions, each one of which I have learnt to associate with the word. Kangaroos I have never seen, but the name suggests to me pictures and descriptions all of which appeal to my own sense-experience.

The material, then, with which mind works can be analysed into sense-impressions, which it interprets and stores up in what we call *experience*. Countless individuals have added to this stock of experience, and made it accessible to others by means of language, whether oral or written. The mind works by giving a meaning to these sense-impressions, by interpreting them, by explaining their relations one to another—in brief, by bringing order and system to what would otherwise be a meaningless chaos like the appearances in certain kinds of dreams.

This attention to order and system is the chief characteristic of knowledge or science. The scientist

aims at building out of the vast mass of human experience an orderly whole, with its parts duly and properly connected, an organized unity, a universe. So large is the material that few scientific men live long enough to do more than to arrange a very few facts, thus bringing nearer to completion a tiny portion of the huge building. But the workers are diligent and numerous. Bit by bit, little by little, the edifice progresses, and though we cannot yet see signs when, if ever, it will be completed, we must be content with the thought that each day registers an advance upon the preceding.

Thoughts are Judgments.

But we must return to our examination of thought. Whenever we interpret our sense-impressions, whenever, in fact, we really *think*, we are as it were pronouncing a verdict. A thought is a judgment:—

This tea is too sweet for me.
The train is on the move.
A cup is standing on the table.

All these sentences are expressions of a verdict, and represent a decision reached by the mind. Now a judgment of necessity implies two things between which a relation is declared to exist. The three sentences given above may thus be divided into their constituent parts:—

This tea | over-sweetness.
The train | movement.
Cup | position on the table.

The Testing of Judgments.

How can we be sure that the connections are rightly made, that the verdicts are true and the judgments correct?

In some cases we cannot prove the correctness at all. If I find the tea too sweet, no amount of argument, no demonstration that only one small lump was put into the cup, will induce me to alter my decision. I alone am a competent judge of my likes or dislikes. As to the motion of the train, I am ready to admit that my eyes may have deceived me, and if a number of bystanders deny my statement I shall probably acquiesce. Another person's judgment in such cases is, given equally good eyesight and equally good opportunities of observation, as likely to be correct as mine. Similarly in the case of the cup and the table. The evidence of better observers or a closer inspection on my own part may possibly lead me to conclude that it is not a cup but a mug, not a standing position but a lying position, not a table but a sideboard. These cases are simple, and not likely to cause any difficulty. But often the greatest care is necessary in testing a judgment. How to do so accurately we learn by studying logic and scientific method. We must now distinguish between them. Strictly speaking, logic deals with the rules to be observed during the process of reasoning. If certain assumptions are made, logic tells us what conclusion we can legitimately draw from them. It does not concern itself with the truth or falsity of the assumptions, but only with the proper way for thought to deal with any material that is put before it[1].

[1] I use *logic* in the sense of *formal logic*.

Logic has no fault to find with the following argument:—

All butterflies have a thousand legs.
This creature is a butterfly.
Therefore this creature has a thousand legs.

The reasoning is quite valid, and logic does not grumble. But logic is far from contented if we say:—

All men have two legs.
This creature has two legs.
Therefore this creature is a man.

The creature may be a man, but the argument does not prove it. The reasoning is not valid, for although all men have two legs, all two-legged creatures are not necessarily men. Some are monkeys. Scientific method, on the other hand, although it makes use of logic, is not content, as logic is, to take statements for granted. It compares statements with reality. It examines butterflies, and shows by observation that they have not a thousand legs. It examines the creature with two legs, and by comparison and contrast shows that it is not a man but a gorilla. Scientific method, in fact, includes logic but goes beyond it by insisting that the judgments with which logic deals shall correspond to reality, the nature of which it tries to apprehend with ever-increasing clearness, using logic as one means to that end.

Grammar.

It will be convenient here to pay a little attention to the meaning of the word *grammar.* Grammar is the science of words. Now it is by means of words, or language, that we express our thoughts or judgments. In so far as they both are concerned with thoughts

there is a close connection between grammar and logic. The fundamental parts of a sentence, the subject and predicate, correspond roughly to the two components which are united by our minds when we make judgments. There are other points in which logic and grammar correspond. But language, which is the subject of grammar, expresses not only our judgments but our feelings or emotions. Man is not entirely a rational creature, and his language often betrays the fact. Furthermore, language is at best an imperfect instrument, and the logical connection of our thoughts is often implied instead of being explicitly stated. You must remember that grammatical accuracy is merely conformity with the ways in which educated people use words; logical accuracy is conformity with the laws of valid reasoning. The sentences given above:—

> All men have two legs;
> This creature has two legs;
> Therefore this creature is a man;

are all quite grammatical. You can parse and analyse them without finding any flaw. Logically, however, the argument is unsound. Remember, then, that grammar deals with words, logic with thoughts.

CHAPTER II

Words and their Meanings.

When a little child is learning to speak he at first attaches to a sound the vaguest of meanings. Any kind of building is, for him, *a house*; anything that causes pleasure is *nice*. As time goes on, sense-impressions are interpreted more accurately, and a more accurate use of words is the result. But perfect precision in the use of language is never attained by anybody; it is therefore all the more necessary for us consciously to exercise ourselves in fixing what meanings words suggest to our minds. There is especial need of care in dealing with words that denote abstractions, such as *justice, courage, wit, cruelty*, or with words that represent, not nature's classes (*horse, cat, butterfly*) but human inventions, e.g., *State, republic, politician, table, machine*. You must remember that the meaning which a person assigns to a word depends in no small degree upon his own experience. He cannot help associating with a word all that he has suffered or enjoyed from the person or thing denoted by it. If a boy's father be habitually unkind or cruel, that boy will also be tempted to associate the word *father* with unpleasant memories of harsh treatment. He must

therefore be continually on his guard against this tendency, and try to assimilate his notion of a father to that formed by the more fortunate majority of children. It is because words thus sum up the past experience of an individual that perfect uniformity of meaning is impossible. I often cannot avoid misunderstanding my neighbour because his use of words is not quite the same as my own. But however impossible it is always to understand fully what is said to us, we must never cease to make the effort. Above all, we must try to take away from the meanings we attach to words that which is peculiar to ourselves, being due to the singularities of our own experience. Otherwise we inevitably fall into confusion, error and futile disputes. How, then, is it possible to use words with greater precision? How do we learn to speak more accurately? I refer, of course, not to grammatical accuracy, but to that accuracy which consists in putting the right *labels* (I mean words) to the things around us. Linguistic accuracy generally accompanies accuracy of observation and of thought. As we learn to distinguish a thing from something else like it, we learn also to name that thing properly. As you learn about moths you want names to give to the different kinds, and as your knowledge increases you use these names with fewer mistakes. Correct classification, in fact, is of immense importance, being the foundation of scientific knowledge. Animals and things are nearly all capable of being grouped. Some groups exist naturally; others are artificial, *man-made*, and therefore far more irregular than the former. It is very difficult, for instance, to know exactly what is meant by a *Conservative*. Conservatives form an artificial group, and

the views of its members are not fixed, but are sure to differ, to some extent at least, from period to period. For this reason it is hard, if not impossible, to define Conservatives. The most that can be done is to state the general tendency of Conservative policy, to enumerate the characteristics which have been common to Conservatives of all periods.

Definitions.

Words denoting abstractions, or which have a vague or fluctuating meaning, such as *courage*, *republic*, *Liberal*, *Church*, always tend, in some minds at any rate, to become mere names unconnected with reality. So powerful is the spell exercised by words that we are inclined to think that we have only to be familiar with a name to be familiar also with the thing the name represents. The best corrective to this fallacy is the habit of framing definitions. As soon as we realize that a word is but a label, a convenient reminder of a person, thing or group, it becomes plain at once why it is important never to allow the connection between word and reality to be broken. Only some parts of reality, however, admit of true, logical definition. Individual persons and things cannot be defined, neither can certain of the most general kinds of reality. We cannot define *Napoleon*; neither can we define *being* or *substance*. Definitions are properly of species, which can be defined by taking the class above and then adding the special characteristics which distinguish the species we have in mind from the other species belonging to the same higher class, or *genus* as it is called. Thus portraits (*species*) are pictures

(*genus*) of real persons or animals (*specific characteristic*). I have used the words "class," "genus," "species," in their ordinary, everyday sense, but scientists use special names when referring to the classes of living things. Thus tigers are the species *Felis tigris*, of the genus *Felis*, of the family Felidae, of the order Carnivora, of the series Vertebrata. The classes are subdivided, and divisions tend to shade into their neighbours. In fact the classification is more a matter of convenience than of strictly scientific accuracy, and the great work of Charles Darwin was to show how a new species develops out of an old one. Nevertheless this method of classification enables us to define natural classes more easily and more accurately than any other.

It is now clear, I think, why only classes, and of these not the highest, can be defined. Only a class other than the highest can be equated with a part of a higher class possessing characteristic qualities which mark it off from the rest of that higher class.

A very good way of defining a class which is not biological is to examine carefully the synonyms of the word used to denote it. For example, suppose we wish to define *stupidity*. This word has many *synonyms*, or words meaning nearly the same thing. Very few, if any, synonyms have exactly the same meaning. The synonyms that suggest themselves are, among others, *foolishness*, *silliness*, *idiocy* and *dulness*. We see at once that there is a general similarity in the ideas these words call to our minds. They all suggest irrational conduct, or a condition of mind leading to such conduct. But irrational conduct exhibits many variations. We must try, by examining sentences in which the synonyms

are correctly used, to discover the special varieties of unreason they represent. We must further remember carefully that what we are in search of is not *our* notion of stupidity, silliness, and so on, but the meanings attached to these words by the generality of mankind. It will probably be decided that by silliness is meant unreason caused by weakness of intellect; idiocy is unreason that reminds one of the actions of certain kinds of madmen; foolishness is the unreason that results from allowing one's brain to be clouded by carelessness; dulness is failure to perceive what the ordinary, rational mind easily perceives. Stupidity is excess of dulness.

Precision of Speech.

The habit of using words in precisely their right meanings is well worth cultivating, as it leads to accuracy of thought and lessens the risk of misunderstandings. It is one which can be formed only by very slow degrees, and this fact is one reason, perhaps the chief reason, why so few people acquire it. A long and wide experience, unceasing vigilance, close attention and acute observation are all necessary, and combined with these qualities there must be a strong desire to improve. To know the chief difficulties and dangers is of great use. We must learn to discriminate between synonyms, to discover the exact meanings attached to words by the best authors, to remember that some words have a technical sense, to realize that a great many words slowly but surely change their meanings, and that care is required in the use of metaphor. The last three points I will explain more fully.

Every science has its own terminology, or technical terms. These are often borrowed from the language of ordinary life, and so a risk of confusion may arise. For example we use the word *idea* to denote an opinion, but psychologists mean by the word a general conception formed in the mind by a series of experiences. Thus they speak of the *idea of justice*, meaning by that the general notion of fairness that gradually grows in our minds as the result of coming into contact with our fellow men. Whenever occasion calls for it care should be exercised, and we should ask ourselves, "Is this word used in its ordinary or in its technical sense?" Then again, a word often changes its meaning. The word *nice*, for example, used to mean *exact*; it now means, in popular speech at least, *pleasant*. *Science* used to mean, and still sometimes means, any knowledge, but it seems to be gradually narrowing its meaning to knowledge of material forces. These are but two instances out of very many, but they suffice to make the point clear.

All languages show a fondness for metaphor, although some languages accept them more readily than others. A metaphor is a compressed simile or comparison. When we speak of a "brilliant achievement," we use the word *brilliant*, which really means shining brightly, in a metaphorical sense. We are in fact tacitly comparing a deed to a bright light. This manner of speaking, while conducing to attractiveness of style and often succeeding in giving to the reader a distinct impression when non-metaphorical language would give no impression at all, is apt to detract from scientific accuracy of expression. Metaphors must always be used with care. Perhaps a strange, really

startling metaphor is less deceptive than one which has been in use so long that it is almost worn out and not a true metaphor at all. It is the confusing of literal meaning with figurative meaning which is likely to cause mistakes, and the more unusual the metaphor the less the likelihood of this confusion occurring. If it be said that a certain rebel raised the standard of revolt in Yorkshire it may reasonably be doubted whether he actually raised a standard or whether he merely started a rebellion in that county. But if I call a cricketer a tower of strength to his side, no such possibility of error arises. A safe rule is never to use a metaphor that may give rise to any reasonable doubt, and never to pass by a possible metaphor without making sure, if we can, that the word or phrase is not to be taken in its literal, non-metaphorical sense. Of course all that I have said applies only to writing in which strictly scientific accuracy is essential. Poetry and prose appealing to the emotions and to the aesthetic sense must be judged by different rules, with which this book does not pretend to deal.

Virtues and Defects of Language.

The usefulness of language is best seen by considering how we should express our thoughts if men were not endowed with the power of speech. We should be confined to gesture and facial expression. These would be fairly efficient ways of showing what we feel, but even when practice had developed our skill to the utmost they would very imperfectly represent what we think. Details, finer shades of meaning, abstractions and generalizations could scarcely be expressed at all,

and constant mistakes and misconceptions would be inevitable. Moreover, progress would be painfully slow, and all the arts and sciences would languish, for language not only expresses thought but also helps it to a degree that is difficult to realize. The two processes, in fact, of thinking and speaking (including of course speaking silently to ourselves) are so closely connected that they have become almost one. So powerful an instrument is speech that man, the only animal endowed with it, has been able, largely by means of its help, to raise himself to a height far above all the others. We must remember also that a permanent record of speech has been discovered in writing, which has preserved for us such a vast amount of human experience which would otherwise have perished, thereby enabling knowledge to accumulate, and science to advance at a rapid rate.

The chief weaknesses of language are:—

(1) It imperfectly represents the emotions.

(2) The meanings of words are largely subjective, that is, words mean one thing to one man and another thing to another man.

(3) Words tend to remain fixed, while the things which they represent tend to change.

Conclusion.

Language is in spite of its great utility an imperfect means of expressing the content of our consciousness. With care we can make it express our intellectual judgments, but it fails lamentably to express our feelings and emotions. Only those who have tried hard

to make others understand what is going on in their minds can appreciate the insuperable difficulty of the task. It is fatally easy to misunderstand; all the easier because we do not always wish to understand, or at any rate are not always ready to take the necessary trouble. Language is perforce somewhat mechanical; while consciousness is living, warm and human. But it must not be supposed that language is entirely mechanical; it lives in so far as it has power by its associations to revive past consciousness. This revival it is always bringing about, but to very different degrees, owing to the different experiences of different individuals, their different ways of looking at things, their different temperaments, their various powers of attention and their degrees of interest.

Few people really want to know the truth, the whole truth, and nothing but the truth. Most men want to be flattered, to hear pleasant news, and to shut their eyes to all that is disagreeable. It is a human failing to crave for comfort. It is a fault with a good side. To fight on and on, to hope against hope, never to know when one is beaten—this is a useful quality for which we should be truly thankful. But it is a quality which is most in place in times of great stress and in critical moments. In the normal course of everyday life it is generally far better to face facts and to look upon the world honestly and frankly. Deep down in our hearts we realize that truth may be unpleasant at the moment, but that it brings its reward afterwards, if not to us at any rate to our descendants. And besides its utilitarian value, truth is loved for its own sake, in spite of the human selfishness and desire for ease which, as I have just said, so often blind us to it.

Curiosity is an instinct only less powerful than the craving for comfort. We want to know; but pleasure, or the fear of pain, bars the way. As psychologists put it, the one instinct *inhibits* the other.

I have said enough to show that the habit of *truth-seeking*, no less than that of *truth-telling*, is one which needs cultivation. We must fight against sloth, love of ease, prejudice, hostility to opponents, greed, in fact against all selfishness that may blind us to reality. The spirit of the debater, whose aim is, not to discover truth, but to score a triumph and crush criticism, is one that needs careful control, or even to be entirely eliminated. Reason must be supreme in our lives, and, with one important exception, refuse to acknowledge any superior. Into this exception I must now go with some detail.

Reason will tell us whether it is possible to realize our wishes, and, if so, how to go to work to realize them. It will tell us whether one wish clashes with another, and how we ought to arrange or systematize our wishes so as to realize the highest. But beyond this it cannot go. It cannot give us our *ideal*. That which we seek for its own sake and not for the sake of anything else, that which we value most in our lives, is not shown to us by exercise of reason. How our appreciation of an ideal comes to us we cannot, in our present state of knowledge, say. It grows and exists, and that is all we know. If a man holds that to be of service to humanity is the highest object to which he can devote himself, reasoning will not persuade him that it is not, any more than it will persuade him that the cup of tea with one lump of sugar in it is sweet if he is not satisfied with less than two.

In the realm of ideals, then, reason fails us. Elsewhere, however, it is an all-powerful weapon. This being so, it is our duty to be on our guard against the imperfections of language, the instrument by which the workings of reason are communicated from man to man. Snares of many kinds, as I have already said, lie all about us. It is so easy to misunderstand, so difficult to make oneself understood. Rhetoric may dazzle us; cleverness may deceive us; our attention may be caught by one statement so that everything else is utterly neglected. Against these and similar dangers there are no safeguards except love of truth and constant practice in seeking it and in expressing it to others.

CHAPTER III

Scientific Method.

Suppose you have before you a basket of apples, and you wish to discover which are best to eat. What you say to yourself is this. "The green apples are not ripe, but the yellow and red ones can do me no harm." This reasoning is really a compressed argument, or rather a compression of two arguments, which, when fully expressed, would run thus:—

Green apples are not ripe, but red and yellow are.
These are green, those are red and yellow.
Therefore these are not ripe, those are.
Ripe apples are good to eat, unripe are not.
Those apples are ripe.
Therefore those apples are good to eat.

This kind of reasoning, in which a particular case is brought under a general rule, is called deduction. But let us suppose that you did not know the general rule that unripe or green apples are not good to eat. How would you go to work? It would be necessary to go through a long series of experiments. You would have to try each apple, and notice (1) its effects when eaten and (2) its appearance, taste and so forth. The next step would be to try to connect (1) and (2). You would

probably conclude that green apples cause pain while yellow and red ones do not. Such a generalization is roughly true, but is not, as you probably know, quite accurate; some greenish apples are not at all bad to eat. The generalization can be improved only by further experiment, and the greater the number of experiments the more exact the *hypothesis*, as it is called, can be made. Some hypotheses sum up the experience of the human race during hundreds of years. This second kind of reasoning, the framing of generalizations, is called induction.

Both kinds of reasoning are valuable, but it is the second kind which increases our knowledge and enables us to acquire greater control over nature; the former kind is chiefly useful in enabling us correctly to make use of knowledge already acquired. Therefore we will discuss induction before deduction.

Induction.

Every valid induction consists of at least three stages:—

(1) The collection of facts.
(2) The framing of the hypothesis.
(3) The testing of the hypothesis.

The facts may have to be arranged or classified as well as collected, and the testing of the hypothesis may result in a modification of it, or even in its entire abandonment. Let us take a simple instance of induction, and pay due attention to the three stages given above.

Problem. In what conditions does a candle burn?

Collection of facts. We notice first of all that in air

a candle will not burn unless it is heated to a certain temperature. We assume then that heat is a necessary condition if the candle is to burn. It is now possible, though perhaps not wise, to frame a hypothesis.

Hypothesis. A candle burns if heated to a certain temperature.

Test. If a certain degree of heat is sufficient to make a candle burn, it will burn if heated to that degree in carbon dioxide. Accordingly we proceed to do this, and find that the candle does not burn. Our hypothesis then was inaccurate. Besides heat, a certain kind, or certain kinds, of air are necessary. We know that the candle burns in atmospheric air, so we now try whether it burns in the separate components of air. Experiments will show us that in nitrogen, one of the components of air, the candle never burns. In the other component, oxygen, it burns readily. We therefore modify our first hypothesis.

Emended hypothesis. A candle burns if heated to a certain temperature in oxygen.

Repeated experiments always confirm the truth of this hypothesis. But if we consider our problem once more we shall see that we have given only a partial solution of it. For all we know there may be other gases or mixtures of gases in which a candle will burn, and in some cases perhaps even heat will not be necessary. Only repeated experiment can tell us whether these possibilities correspond to reality or not.

The example just given well illustrates the danger of hasty, and therefore imperfect, generalization. Haste, in fact, is the cause of most of the mistakes made in scientific inquiry. Whenever the evidence is not sufficient, the only scientific thing to do is to refrain

from framing a hypothesis until more evidence is obtained. Strictly speaking, we ought to collect every shred of available evidence before generalizing, but to this rule there is an important exception. This exception is really a concession to the weakness and imperfection of the human mind. To collect all the evidence is sometimes too laborious a task; so a representative part is taken and a *working hypothesis,* as it is called, formed from it. This working or tentative hypothesis is only provisional, and it must be continually tested by comparison with reality as new evidence presents itself. Should facts be discovered which will not fit in with the hypothesis it must be modified or abandoned at once. Truth must never be ignored or distorted in order to save a hypothesis. The human mind is often tempted to be dishonest in this way, because it is natural that a hypothesis should be loved by its author; it has been said that the "saddest sight in the world is a theory slain by a fact." I will now show the usefulness of a working hypothesis by considering what the factors are that determine the position of large cities.

To solve this problem fully it would be necessary to examine the sites of every large town that exists or has existed, and to inquire into the history of the foundation of each one. But a great deal of this evidence has perished, while to collect and examine all that does exist is a very long and laborious work; indeed it could not be done at all were it not for the patience and diligence of numberless geographers and historians, living and dead. Unless, therefore, we are prepared to devote months or even years of unremitting toil to the solution of this problem we must be content with a working hypothesis derived from such evidence as is

of easy access, and, aware of its tentative nature, be ready to modify or abandon it at any moment. We might open a gazetteer at random and choose any twenty-five towns with over 30,000 inhabitants. An examination of the sites, combined with the study of history, would probably show that the main reasons for the rise of these towns are:—

(1) Nearness to a trade route.

(2) Situation in a region of great natural fertility.

This classification of the evidence leads to the formation of a provisional hypothesis, which subsequent experience will modify, probably by the addition of other reasons for the choice of sites.

It must not be thought that the mere application of certain rules will lead to important discoveries. Scientific method is not a machine; it will not work by itself, but needs the co-operation of human qualities. Care, thoroughness and observation are required for the collection of evidence; insight and imagination are essential for a good hypothesis; acuteness must be exercised in applying tests. Some important discoveries appear to have been little more than brilliant guesses; so rapid, so intuitive was the working of the scientist's brain. Drill and routine, however, are by no means to be despised. They are useful even to the genius; while to the rank and file they are invaluable, and it must be remembered that to the laborious spade-work of obscure persons is due many a clever hypothesis framed by a greater mind.

When we test a hypothesis, sometimes we look out for fresh evidence, and sometimes we conduct an *experiment*. The essence of an experiment is to allow natural forces to work when under the control of the observer.

Suppose, for instance, it is observed that wheat grows well in certain districts, and we wish to know which quality, or which qualities, of these districts produce the good results. Possibly we may frame the hypothesis, after due consideration of all the districts, that their fertility is caused by the amount of water at a certain depth below the surface of the soil. If by drainage we can vary this amount of water and then grow a crop, we have a very good test of our hypothesis. Should the crop be as good as before, the hypothesis was wrong; should it be inferior, the water was one cause, and perhaps the only cause, of the fertility. Whether other causes were operating can be decided only by varying the other conditions one at a time. If more than one condition be varied at one and the same time, it is impossible to decide whether any resulting change is caused by one factor only or by more than one.

Before going on to discuss the nature of evidence it will be wise to recapitulate what I have already said about hypotheses. It is such an important question that a little repetition can do no harm.

Recapitulation.

A hypothesis is a statement of a unity assumed to underlie a number of facts. In other words it is an attempt to explain phenomena by pointing out how they are related. If you see a doctor's carriage outside the house of a friend who is often ill, it is a hypothesis to suppose that the doctor has been called in to attend your friend. This is an eminently reasonable but not necessarily a correct hypothesis. The carriage may

be where it is by accident, or the doctor may be attending another inmate of your friend's house. A traveller might perhaps sum up his experience in the hypothesis that all good hotels are expensive. This hypothesis, again, is likely to be true, but the discovery of a good, cheap hotel would necessitate a modification of it.

The most valuable hypotheses are those which state a general rule summing up a number of particular instances. These make progress possible by putting information in a handy form. These hypotheses, when well verified, themselves become data for yet wider generalizations, and this process is ever going on under the guidance of our scientific workers and thinkers. In this way our knowledge is becoming more and more ordered and organized as well as wider and deeper.

Some hypotheses can be conclusively proved or disproved by a little inquiry. It would not take long, for instance, to find out whether in the example given above the doctor was or was not visiting your sick friend. But in other cases complete verification is absolutely or at any rate practically impossible, however highly probable the hypothesis can be shown to be. That all diamonds will cut glass is a hypothesis which has been confirmed millions of times; you may be confident that any particular diamond will have this power. Yet at any time, however unlikely the supposition, a diamond may be found too soft to cut glass.

If two volumes of hydrogen and one of oxygen be mixed and then exploded, the result is that all the hydrogen and oxygen disappear, and a little water is formed. The experiment has been performed a countless number of times and the result is always the same.

Scientists are thus enabled greatly to shorten their work. One experiment carefully performed is often sufficient to prove a new generalization. Hypotheses, however, which are based on one experiment are often wrong, because it is difficult to make quite sure that all the conditions have been taken into account. Without our knowing it, an essential condition in a first experiment may have been a temperature of no more than 70° C. In a second experiment the result will not be the same if by accident the temperature is raised to 73° C.

Evidence.

By evidence we mean accurately observed phenomena of all kinds which seem to be causally connected. Other words used to denote the same thing are *data*, *facts* and *material*. The collection of facts is usually a long and laborious process, but obviously no advance in science is possible without it. It will be useful to examine the nature of evidence by taking a very common type of problem. We are constantly applying scientific method in our everyday life; there is only one way to discover truth, whether that truth be important or trifling. Suppose a short-sighted person were going along a country road and observed a black object moving towards him in the distance. He might argue in the following way:—

"Since the object is moving steadily it must be either alive or mechanically propelled. No motor or bicycle would use this bad road when there is a good road a few hundred yards to the right leading to the same destination. It may be a black animal, but no animal that I know of is of the shape and size it appears

to have. It looks like a man, and I was told in the last village that the postman passes along this road at about this time. Now that I come to think of it, the pace is too slow even for a bicycle, and I think that I can see a postman's pack. I conclude that it is the postman and that he is dressed in very dark clothes. If I wait until my short sight has a better opportunity I shall be able to test my conclusion."

The evidence used by this person can be classed under three main heads:—

(1) Sense-impressions, i.e. the shape, size, colour and movement of the object.

(2) Past personal experience, i.e. the size and shape of various animals and of men, the speed of motors and of bicycles, and the improbability of meeting these on bad roads.

(3) The testimony of other people, i.e. the information about the postman.

My analysis is not quite complete, but it is accurate enough to illustrate the points I wish to make clear. The first is that both (2) and (3) consist of generalizations, which have been reached as the result of many past experiences. Such generalizations are often of value as furnishing material for yet wider generalizations or (as here) because they can be applied as tests to tentative hypotheses. What really has taken place in the mind of the short-sighted person is as follows. He has observed a moving, black shape. He then proceeds to make a series of hypotheses, which he tests one by one. Each test is a deduction from a well-established generalization. One example will make the process plain.

Hypothesis. This object may be a motor.

Test. If it is a motor, like all motors it will keep if possible to good roads. But the road on which it is is a bad one, although a good one is available. Therefore the object is not a motor.

The third kind of evidence is a statement (in this case a general one) accepted on the authority of others. This sort of evidence is very important, and great care must be taken to measure correctly its credibility. The science of history depends largely upon the testimony of others.

Bearing in mind this analysis let us consider another simple problem. A medical officer is summoned to investigate an epidemic of scarlet fever in a small town of 20,000 inhabitants. His object is to discover the cause of the outbreak, in order if possible to remove it. He first has a list made of all the cases, with the addresses of the patients and the dates of their coming under medical supervision. There are in all 530 cases. These are not confined to one quarter of the town, but certain streets suffer very severely, although widely separated, while other streets close to one another scarcely suffer at all. Houses seem to be attacked rather than single individuals. There are many houses in which nearly every inmate, with the exception of those immune through having had the disease before, has fallen a victim. A week before there were no cases at all in the town; for the last four days they have been occurring at the rate of over 100 a day.

Such is the evidence before the medical officer. It should be noticed that, whereas in the last problem certain simple sense-impressions required interpretation, it is now a question of interpreting again a number of interpreted sense-impressions. Moreover, the officer

takes most of the evidence on trust, accepting as true the statements of his co-workers. If these are both capable and trustworthy he is quite justified in so doing, but if he doubts either the capacity or the honesty of any one of these it is his duty to verify all testimony received from him. We will assume, however, that such verification is not necessary.

The officer now proceeds to frame a tentative or working hypothesis. Is it an instance of simple infection from patient to patient? This hypothesis is at once rejected because of the officer's past experience and the knowledge he has gained from the experience of other observers. It does not account for the suddenness of the outbreak, nor yet for the simultaneous seizure of whole families. An epidemic caused by repeated contact would be gradual, and would probably spread from district to district surely but slowly. The swift onslaught of the epidemic under consideration points to a cause affecting large numbers of people at one and the same time. So the officer frames another hypothesis. He has heard that at a village five miles away scarlet fever has occurred several times during the last few months. Once more the evidence is but testimony depending upon the authority of others, but there seems to be no reason to distrust it. This village sends milk to one of the chief milk distributers of the town. Accordingly the new hypothesis is that the epidemic is due to contaminated milk. The officer knows that outbreaks are often caused in this way. This hypothesis is tested by a deduction which will correspond to facts if the hypothesis be correct. If milk be the cause of the outbreak, the "fever map" will correspond to the "round" of some milkman.

Investigation shows that the infected houses are in every case supplied by the milkman who gets his milk from the infected village. The hypothesis is now almost certainly correct, but in order to be quite sure of his ground the officer makes inquiries at the suspected village, and finds one of the chief milkers suffering from scarlet fever in its most infectious stage. This man is isolated, the supply of milk from the village is suspended and the epidemic rapidly declines.

These instances show very well that evidence does not always consist of uninterpreted sense-impressions. Data are often the results of a whole series of inferences and interpretations, which in very many cases depend upon the capacity and honesty of numerous observers. It may be said, I think, that the careful investigator will always bear in mind the necessity of realizing which kind of evidence he is using and the ways in which error may creep into each. Sense-impressions may be misinterpreted; generalizations may be faulty; witnesses may be incompetent or dishonest.

Of all evidence that which rests upon the authority of others is the most liable to error. Few men are perfectly honest; we are all occasionally guilty of allowing our intellect to be perverted by our emotions. No man can be a just judge of an adversary. Then again, however honest we may be, we may make intellectual mistakes through lack of power or through carelessness. Finally, whether these dangers are overcome or not, we may express our conclusions in faulty language conveying to others a series of wrong impressions. It is not wonderful that testimony depending upon the authority of others always stands in need of the closest scrutiny before it can be accepted.

We must now consider some of the tests that can be applied to the testimony of others in order to estimate its credibility. We can bring forward evidence of two kinds:—

(1) intrinsic;
(2) extrinsic.

By "intrinsic" evidence is meant a consideration of the inherent probability that an alleged occurrence took place. If a statement be in accordance with normal experience it is more likely to be true than if it is opposed to it. But even if the statement be in itself likely, its credibility is doubtful if its author be known to be inaccurate, habitually untruthful, or likely to profit by telling a falsehood. By "extrinsic" evidence is meant a consideration of the statements of other witnesses or of well-ascertained facts. If extrinsic evidence be perfectly reliable, it may convict a statement of untruth, or, on the other hand, it may strongly confirm it. A very common occurrence is that two statements, made by two different authorities of nearly equal credibility, contradict each other. To decide which of the two statements is true is then a matter of the greatest difficulty. Sometimes it so happens that a piece of extrinsic evidence presents itself which is of such a kind that one or other of the statements is strongly confirmed if not proved, but sometimes we have to be content with an uncertainty of the vaguest kind. The science of history is almost entirely dependent upon evidence the truth of which cannot be proved. But usually there is no reason to doubt the general accuracy of our authorities; when two clash it is in most cases possible to say that one or the other is more likely to be true; in a few cases, however, the evidence

on either side is evenly balanced, and it is quite impossible to decide which is the more likely view to hold.

Decision between conflicting testimony is the task which faces our judges and jurymen when they are trying a case. The lawyers of both parties do their utmost to put their side of the question in the best possible light, and there is little chance of any pertinent evidence or plausible interpretation being overlooked. Perhaps a greater danger is that a brilliant advocate, by clever rhetoric or by the magnetism of his personality, may blind the jurymen to the conclusion to which the evidence really points; the judge, however, is specially trained to detect such disturbing influences, and puts the jurymen on their guard when he addresses them.

Every day of our lives we are occupied with the same task of solving little problems in which we have to decide between conflicting evidence. Suppose for instance that we are marketing and wish to buy some fish. We go to a fishmonger and ask for some plaice. He gives us the quantity asked for and assures us that it is fresh. But when we see it we have our suspicions of its quality, and friends have warned us that this particular dealer is not always to be trusted. How are we to decide whether we ought to buy the fish or not? Are we to believe the fishmonger or our own suspicions? Now the former has a reputation for deceit, and the hypothesis that the fish is not fresh fits in better with the data before us. Therefore, if we are wise, we shall refuse to buy the fish.

Problems such as this constantly present themselves for solution in the lives of all of us. We are so used to them that we are rarely conscious of going through the

stages of a formal proof. Our mind works rapidly and as it were by intuition.

In collecting evidence and in examining it accuracy is essential. Accurate measurement is the basis of all science. Not only accurate reasoning but also accurate senses are necessary. To be able to make a line of exactly a given length, to distinguish slight differences of colour, smell or taste, to notice minute changes, all these powers are at least as important in scientific work as logical acuteness. Many an experiment has been an utter failure just because some slight error has occurred in measurement, and many a discovery has been missed through failure to observe a slight change in the course of an experiment.

Classification.

In many cases we find that the evidence after being collected needs arranging. Suppose for example that we are considering the resemblance of certain animals to their environment. When all the facts have been collected it is found that they naturally fall into two groups: (1) cases in which the resemblance enables an animal to escape from an enemy; (2) cases in which the resemblance enables an animal to capture its prey. This classification greatly facilitates the framing of a hypothesis.

We classify things and arrange them into groups because of likenesses and unlikenesses. We put into one group all things that are brown, into another all things that are green, and so on. Again, we can arrange things according to size or shape, and persons according to their physical or mental characteristics.

But when we are classifying for scientific purposes we must be careful not to be misled by resemblances which do not affect our problem. Only those count which are actually related to the special point that we are considering. If we have to classify books for a library we gain nothing by dividing them into groups based upon the colour or the material of their binding. An index of bindings would be of no use to a student consulting the library. We shall probably base our classification upon the subject-matter of the books and place all the history books in one group, all the novels into another group, and so on. An index of authors is also very useful, and the various subjects might be re-classified upon this basis. The most important thing to avoid in classification is what is known as *cross division*, in other words our groups must be mutually exclusive. It would never do to divide men into (1) good men, (2) Frenchmen, (3) one-legged men, (4) dark men, (5) clever men, and (6) old men. This example is obviously absurd; the groups are not mutually exclusive, and the classification, if such it can be called, serves no useful purpose whatsoever.

Knowledge itself has often been divided into groups, but a classification of the sciences can never be really satisfactory. The universe is a unity, and science, that is man's comprehension of the universe, must be a unity also. All attempts to divide this unity necessarily fail. Nevertheless even an imperfect classification of the sciences is useful for practical purposes, and an attempt to classify them will at any rate demonstrate how intimately connected they all are.

First there is a group of sciences which deal with

the properties of matter, whether animate or inanimate, and with the forces which manifest themselves in conjunction with matter; e.g., chemistry and heat.

There is another group that deals with the phenomena peculiar to living bodies; e.g., physiology and botany.

There is another group dealing with animals, and in particular with man, in so far as they are conscious beings with instincts, impulses, desires and reasoning powers. In this group are included ethics, psychology and logic.

The mathematical sciences deal with the properties of number and space.

Each of these groups is subdivided, and there are certain sciences which belong to more than one group. Geography, for instance, has affinities with geology, which is one of the physical sciences, and with sociology, which belongs to the same group as ethics. Where ought history to be placed? Being the story of human development it is akin to sociology, but geographical factors have exerted such a powerful influence upon man that its relationship to geography cannot be denied. The science of language is another one which is very difficult to place in a definite class. We are learning more and more every day how strong is the influence of physiological factors upon the history of language, but it is the laws of mental life that determine most linguistic phenomena.

The various sciences, in fact, shade into one another. Forms of energy are constantly changing without the amount of energy becoming either greater or less. Heat passes into electricity and electricity causes chemical action; motion is exchanged for heat and

heat for motion. No definite line can be drawn between one natural class and its near neighbours; Darwin's great work was to show how species gradually give rise to other species. Similarly the sciences are not separated by hard and fast boundaries. Nevertheless, in spite of the absence of fixed limits, there is a difference between one natural class and another and between one science and another. We may not be sure where heat begins and chemistry ends, but we are quite certain that when iron rusts it is a phenomenon of chemistry and not of heat.

As our knowledge grows we realize more clearly the unity underlying it. At the same time the sciences tend to increase in number through subdivision. A few years ago a great French scholar, by carefully investigating the changes that take place in the meanings of words as time goes on, founded the science of *semantics*, a subdivision of the science of language. Other new sciences are *eugenics*, a branch of biology, dealing with the laws according to which characteristics are transmitted from parent to offspring, and *biochemistry*, a branch of chemistry dealing with the chemical changes that take place in living bodies.

Notable Examples of Scientific Discoveries.

(1) One of the most interesting examples of scientific induction is to be found in the history of malaria. Malaria is a fever which from the very earliest times has afflicted dwellers in the neighbourhood of marshes. Very naturally the ancients concluded that the disease was caused by the water, or by exhalations from it. This view was held until quite modern times, and as

to avoid marshes was followed by excellent results, there did not seem to be any reason to abandon the theory. But modern science was not satisfied. Why are some marshes unhealthy and not others? Why should autumn be the most unhealthy season of the year? These and many other considerations of a like nature caused scientists to search for another hypothesis. A famous doctor, Sir Patrick Manson, argued that malaria might be caused not by marshes but by something that can only be found near marshes. So he suggested that the disease was caused by the bite of a mosquito. This suggestion was little more than a guess. But it attracted the attention of a doctor of the Indian Army, who is now Sir Ronald Ross. Several years before it had been proved that in the blood of malaria patients there could always be found by the aid of the microscope certain parasites in one stage (the asexual) of their development. This process of reproduction cannot go on indefinitely; a sexual stage must occur somewhere, and there were several strong reasons for supposing that it took place outside the human being. The question before Ross was this. Could he find signs of this sexual stage in the blood of mosquitoes? For over two and a half years he worked incessantly, examining under the microscope many thousands of insects without the slightest sign of the object of his search. Practically all this work was done on one species of mosquito, which happened to be the most common kind in that region of India in which Ross was working. Almost in despair, he chanced to receive from a friend a different mosquito, and in the walls of its stomach he found the black pigment which is deposited within the body

of the malaria parasite as it feeds and grows. Further investigation showed that this substance could always be found in the walls of the stomach of this species of mosquito a few days after it had bitten a malaria patient. This discovery was made in the year 1898. Two more years of study and experimentation unfolded the whole life-history of the parasite, both its asexual stage in man and its sexual stage in the mosquito. Only the Anopheline group, it was shown, could carry malaria from man to man.

In 1900 two English doctors lived in the Roman Campagna, a district infested with malaria, for the worst months of the year. They exposed themselves freely to all kinds of weather, and did everything popularly supposed to cause malaria, but they protected themselves with the greatest care against mosquito bites. They took no quinine, the recognized specific for malaria. Although all their neighbours had malaria, they themselves were entirely free. Finally, mosquitoes which had bitten malaria patients in Rome were sent to England, which is a non-malarious country, and allowed to bite two volunteers. Both contracted malaria. No other means of transmitting the disease has been discovered, but over and over again, in all parts of the world infected with malaria, the destruction of Anophelines has brought about a marked diminution of the number of cases. Whole regions, once scarcely habitable, are now perfectly healthy; so wonderful is the effect of drying up the breeding-places of the mosquito, or, if this be not possible, of destroying the larvae by covering all likely puddles with oil, which suffocates them. Mosquito-nets and screens are an additional protection.

(2) Yellow fever, the "Yellow Jack" of our old sailors, is a highly infectious, very dangerous disease, prevalent on the West coast of Africa and in the West Indies, and often occurring in epidemic form in the southern regions of the United States. In 1905 a severe outbreak took place in New Orleans, causing nine hundred deaths. But by the application of a scientific discovery it was checked just at the time when according to all past experience it should have been at its height. Yellow fever was one of the greatest obstacles to the construction of the Panama Canal, but here again science has succeeded in wiping out the scourge. This discovery, which has been of such enormous practical value, well illustrates the method by which experiments decide between two rival hypotheses.

During the American occupation of Cuba the disease became very prevalent in the island, and a board of four doctors, Reed, Carroll, Lazear and Agramonte, was appointed in 1900 to study the disease in Havana. At the time there were two theories as to the transmission of yellow fever. The dominant one was that bedding, clothing and so forth, which had been exposed to the excreta or vomit of a sufferer, spread the disorder. The other was that a mosquito, *Stegomyia calopus* (*fasciata*), causes it by biting first an infected person and then a healthy person. The latter theory was supported by the very similar case of malaria, which in 1898 was shown to be due to the bite of another kind of mosquito. In order to test this hypothesis certain people, one of whom was Dr Carroll, allowed themselves to be bitten by mosquitoes which had previously fed upon yellow-fever patients.

Three days after being bitten Dr Carroll sickened and nearly died; another member of the board, Dr Lazear, was accidentally bitten and contracted the disease with fatal results. These preliminary experiments encouraged the investigators to apply yet more stringent tests. An experimental sanitary station, called Camp Lazear after the martyr to science, was established in an open field near Quemados. Here were built two rooms, each 14 by 20 feet in size, known respectively as the "infected clothing building" and the "infected mosquito building." The former was so constructed that there was no efficient ventilation and no mosquitoes could enter. The latter was perfectly ventilated, and screened so as to keep mosquitoes in it as well as to keep out others. Through the middle ran a mosquito-proof screen. Into the former building were brought sheets, blankets and so on, soiled by contact with yellow-fever patients. Three volunteers, who had never had the disease and so were non-immune, unpacked these articles, made beds of them and slept in them for twenty days. The experiment was repeated three times. No case of fever resulted. Into one part of "infected mosquito building" were introduced fifteen mosquitoes that had fed on patients at least twelve days before. A non-immune exposed himself in this room to the bite of these mosquitoes, and soon after developed the disease. At the same time two other non-immunes entered the other compartment, where they slept for eighteen nights separated from the the infected mosquitoes by the screen. Neither of them caught the fever. By continual experiment, calling for great heroism in the volunteers, it was shown that at least twelve days must elapse after biting a patient

before a mosquito can infect a healthy person, and that there is no other way of spreading yellow fever except by inoculation with blood from a patient in the first two or three days of the disease. The minute organism causing the disease has never yet been isolated. It is too small for our microscopes to detect.

Conclusion.

Such in outline is the *method of discovery*, to call induction by a more graphic and significant name. By means of it scientists are rapidly increasing their control over the forces of nature, and their recent successes appear little short of miraculous. Sometimes a success is the result of a brilliant guess, more often it is the outcome of much careful toil. In many cases a large band of workers is set to attack one problem. Each little portion is assigned to one scientist or perhaps to two. After doing the task assigned to him, which probably involves a vast amount of observation and experimenting, the research student writes a full account of his work and the conclusions he has reached. Other skilled scientists consider the various reports and try to combine them into a harmonious whole. Very often fresh research is shown to be necessary by this first examination of results. Finally, however, if all goes well a definite conclusion is reached, and the new discovery may perhaps bring untold relief to mankind by stamping out a dangerous and painful disease.

Deduction.

For centuries deduction was regarded as by far the most important part of logic. It was studied and elaborated with the utmost care, and it was considered

to be the chief instrument in the acquisition of knowledge. Aristotle, who first laid down the rules for correct syllogisms, was thought to be the supreme authority in the art of reasoning, whose supremacy it was impious to question. With the rise of modern science, the object of which is discovery, induction grew in importance and deduction fell into disfavour. The exaggerated importance attached to deduction and its subtle niceties now made the pendulum swing too far in the opposite direction, and resulted in undue disparagement. It was a long time before it was realized that each had its own function and that neither was complete without the other. It was perhaps a loss that deduction was over-systematized. The minute rules for the construction of valid syllogisms tended to make reasoning mechanical and lifeless, besides obscuring its essential nature. The main principle of deductive reasoning is simple and easy to understand. It is briefly this. Whatever is true of a class is also true of every member of that class. If, for example, it be true that all animals die, and also that X is an animal, we may be certain that X will die sooner or later. It is obvious that generalizations like "all animals die" are all discovered by induction, and that deduction merely enables us to make full use of such discoveries.

This is nearly all it is necessary to know about deductive reasoning, formal specimens of which are called *syllogisms*. A syllogism consists of three parts, called respectively *major premise*, *minor premise* and *conclusion*. The most important kind of syllogism is technically known as *Figure I*. In it the major premise is always a general or universal statement; the

minor premise may be either universal or particular; the conclusion can be universal only if both premises are universal.

The following are specimens of syllogisms.

(1) All animals are mortal.
All men are animals.
Therefore all men are mortal.

(2) No gas is lighter than hydrogen.
Oxygen is a gas.
Therefore oxygen is not lighter than hydrogen.

(3) All plums have stones.
These fruits are plums.
Therefore these fruits have stones.

If the general principle of the syllogism be thoroughly understood there is little need to learn the technicalities with which deductive reasoning has been overlaid, but there are a few rules and bits of terminology which may prove useful.

Statements or expressions of judgments are called by logicians *propositions*, and strictly consist of two *terms* united by the verb "to be" called the *copula*. The term which occurs in both premises, but not in the conclusion, is called the *middle* term. The subject of the conclusion is the *minor* term; the predicate of the conclusion is the *major* term. A term is *distributed* when we make a statement about all things which can be included under the term.

Two Rules of Quality.

(1) For an affirmative conclusion, both premises must be affirmative.

(2) For a negative conclusion, the premises must be opposed in quality.

Two Rules of Distribution.

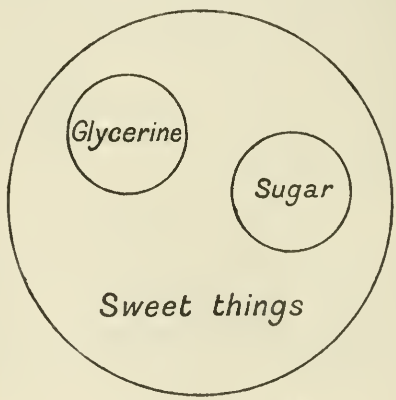
(1) The middle term must be distributed in one at least of the premises.

(2) Neither extreme term must be distributed in the conclusion unless it is distributed in its premise.

Failure to observe these rules results in *fallacies*, of which a good example is:—

All sugar is sweet.
All glycerine is sweet.
Therefore all glycerine is sugar.

The middle term "sweet" is not distributed, and the syllogism is a fallacy. But a much better way to detect the fallacy is to examine carefully what the propositions really mean, and so find out where the error lies. Now it will be seen that sweetness is a very wide term, and sweet things may include sugar, glycerine, saccharine and many other substances. It is therefore not legitimate to infer that because things are sweet they are necessarily the same. We might express the facts by circles, each circle denoting a term, thus:—



Although the circle marked "sweet things" includes the circles marked "glycerine" and "sugar," the two latter for all we know do not overlap, and we must not infer that glycerine is sugar.

Syllogisms should be examined in this way, which is much better than trusting to mechanical rules, however useful these may be as occasional tests.

Analogy.

By arguing from analogy is meant concluding that because two things are alike in one or more than one respect they are also alike in another respect or in other respects. In the rough and tumble of everyday life we are compelled to make constant use of analogy and to act upon the conclusions it suggests. But our being compelled to use it is no reason why we should shut our eyes to its dangers. We ought never to argue from analogy without realizing the inherent uncertainty of the process.

Children often make funny blunders owing to the hold analogy has upon their minds. They know, for instance that the plural of *house* is *houses*, and they go on to infer that the plural of *mouse* is *mouses*.

Analogy is justifiable when the resemblance between the two things compared is very close, and if besides it is remembered that any inference drawn is nothing more than a possible or probable hypothesis. Many scientists are of opinion that there is life on the planet Mars. It is so like our Earth in many respects that there is no reason to doubt that all the conditions necessary for life are present. But we cannot regard the question as proved. It remains, and seems likely to remain, a probable hypothesis.

When we generalize, we frame our hypothesis on the close resemblance of many things in perhaps only one respect. In arguing from analogy, on the other hand, we generally frame a hypothesis on the resemblance of two things in several respects. There is thus a close resemblance between analogy and induction.

Fallacies.

A fallacy is a piece of reasoning which appears to be correct but really is not so. A playful instance of a fallacy is the following syllogism.

Every cat has one more tail than no cat.
No cat has two tails.
Therefore every cat has three tails.

In form the argument is quite correct; the explanation of the fallacy is that the term "no cat" in the major premise does not mean the same thing as the term "no cat" in the minor premise. As men every day of their lives reason about a hundred matters so rapidly that the stages of thought are slurred over or even omitted entirely, it is not surprising that fallacies are constantly occurring. They are of many kinds, and I can describe only a few of them.

Fallacies of the type given above, caused by a term having two meanings, are called fallacies of equivocation. The most interesting of the other types are generally known by their Latin names, which are: *ignoratio elenchi*, or irrelevant conclusion; *petitio principii*, or begging the question; *post hoc, ergo propter hoc*, or fallacy of false cause; *non sequitur*, or fallacy of the consequent.

If an advocate cannot prove that his client did not commit the theft of which he is accused, and so spends

his time in showing what a brave soldier and excellent father he has been, the facts stated may all be quite correct, but they are not "to the point," and the advocate is guilty of *ignoratio elenchi*.

Begging the question is assuming the point which has to be proved. A very common form of this fallacy is to let our likes and dislikes determine our notions of right and wrong, which begs the whole question of the nature of good and evil. Suppose a man is trying to prove that alcohol is not injurious. He might urge that "it never did *X* any harm." If this statement is founded on scientific evidence that would satisfy a critical board of medical men, it is valid testimony, although by itself it is insufficient to prove the point at issue; but if it is merely a hasty, ill-considered remark, the speaker is obviously begging the question.

One of the commonest fallacies is to imagine that *post hoc* (after this) necessarily implies *propter hoc* (on account of this). A misfortune happens to occur or to be heard of the day after a bad dream. The dreamer, unless he be very strong-minded, is likely enough to conclude that the one caused the other, or at any rate that the two incidents are causally connected in some way. To hold that an attack of sickness is due to one's last meal may be reasonable if the view be held merely as a hypothesis; to say that the meal must be the cause is to be guilty of a bad fallacy, unless indeed there be other evidence than the bare fact that it preceded the attack.

A *non sequitur* is committed when a conclusion is drawn which does not follow from the premises. It is really a faulty syllogism, and in a way all faulty syllogisms are fallacies, although the name is usually

applied only to such syllogisms as appear to be correct in spite of their faultiness. The following is an instance of a *non sequitur.*

> No grasses are poisonous.
> This is grass.
> Therefore it will make bread.

It is legitimate to argue that the grass in question is harmless, but we cannot properly infer that its seeds will make anything worthy of the name of bread.

Reason and Authority.

Everyone ought periodically to ask himself in what way or ways he is acquiring fresh knowledge. It is impossible to go through the whole process on every occasion, but the practice should be regular and systematic. We will take a few instances. How do we learn that one of the commonest ways of expressing purpose in Latin is by the use of *ut* and the subjunctive? One way is to get the information from a grammar book. If we do so we take the statement on trust, there being no reason, in all probability, to doubt the word of the writer. But how did the writer acquire his knowledge? Perhaps from another grammar writer, in which case he too took his information on trust. Obviously, however, somebody or other discovered the rule by the process of induction, and it is quite possible for us to discover it in the same way. We may, for instance, in the course of our reading of Latin notice that *ut* and the subjunctive are used in a sentence which clearly expresses purpose. Later on we notice the same phenomenon, perhaps several times. So we frame the hypothesis that purpose is, at any rate

sometimes, expressed in this way. This hypothesis is tested again and again in the course of our reading.

Let us take an example from history. How do we know that the Spanish Armada was defeated in the year 1588? Nobody now alive could have seen the battle, and so it is necessary to rely upon the testimony of documents. The evidence of these has been sifted many times by competent historians, and a fairly reliable account of the fighting has been thus drawn up. It doubtless contains a few errors of detail, but the general outlines of the story are reasonably certain. These outlines are given in the school text-books, from which our knowledge is usually derived.

In geometry we assume certain propositions as self-evident and from them deduce certain conclusions. These conclusions we use as premises from which to deduce other conclusions. In this way a whole science is built up. Nothing is taken on trust; every step is understood and commands our intellectual assent. That the three angles of every triangle are equal to two right angles is a proposition which cannot be denied by anyone who has assented to the definitions and axioms which are the foundation of the science of geometry.

In studying the natural sciences we use both inductive and deductive reasoning, while to a certain extent we rely upon the authority of experts. But the statements of these experts can always be tested by students who have sufficient knowledge and skill to make the necessary experiments. If we are told that conditions X, Y, and Z produce result A, we can always appeal to nature to see if it really be so. This statement is not invalidated by the fact that only

trained investigators can in certain cases conduct the experiments required to prove the point.

When, therefore, you ask yourself how you obtain a fresh piece of knowledge, first of all inquire how far you are relying upon your own reason, and how far upon the authority of others. It may be that the question of authority does not come in at all, but if it does, go on to ask whether it is possible to apply the test of an appeal to reality. If it is possible, apply it yourself, or at least find out whether others have applied it already; but if it is not possible (as for instance in the case of many history problems) you must take steps to estimate the credibility of your authority, remembering that no absolutely certain conclusion can be reached. The question is one of greater or less probability.

The testing of authority by an appeal to reality is well illustrated by the research of a mathematician named John Adams, who was afterwards a famous astronomer. When quite a young man he was puzzled by the strange and irregular movements of the planet Uranus. The hypothesis occurred to him that there might be another planet, unknown to astronomers, which, by the attractive force which all bodies exert, was influencing the movements of Uranus. He proceeded to make calculations as to the probable direction in which this planet could be observed, and concluded that in a certain spot a planet of a certain size would be seen by the help of a sufficiently powerful telescope. He wrote to Greenwich asking the Astronomer Royal to verify his hypothesis, but as he was an unknown man his request was ignored. Some time later a French astronomer came to the same conclusion as

to an unknown planet. Being more fortunately situated than Adams he was able to apply the simple test of "look and see," and so discovered the planet Neptune.

ADDITIONAL NOTE.

In this little book I have used the word *hypothesis* to denote any interpretation of phenomena, however simple or however complex that interpretation may be.

You will notice that these interpretations are of at least three different kinds.

(1) They may result in particular propositions, e.g.:

That is an apple.

The disease that he is suffering from is influenza.

(2) They may result in general propositions of such a kind that every instance can be examined and brought under the general rule, e.g.:

Ut meaning *in order that* always takes the subjunctive in Latin. (Every instance of this construction in Latin literature has been noted and examined.)

(3) They may result in general propositions of such a kind that every instance cannot be examined, e.g.:

All animals require food. (This statement is true so far as we know, but some day science may possibly discover, perhaps in another planet, animals which do not require food to maintain life.)

Some logicians use the word *hypothesis* in a narrower sense, and you must not allow this lack of uniformity to cause confusion in your mind when you are reading other text-books.

APPENDIX

EXAMPLES OF INDUCTIVE REASONING DONE BY BOYS

I.

Problem. Why are large towns situated where they are?

STAGE 1. COLLECTION.

N.B. Here is need of an obvious caution. It is impossible, for me at least, to collect the evidence of all the towns that ever were. Many have long since perished, and of those thousands now existent we can hardly examine more than a few. Let us take then, roughly speaking, the world's chief cities as fair examples of the whole.

London. On the mouth of the Thames. Harbour. Ancient military position.

Edinburgh. On a mount commanding the whole neighbourhood.

Dublin. On a natural harbour. River.

Paris. On a navigable river, at junction with two tributaries.

Brussels. On small river. Central position in kingdom.

Amsterdam. River mouth.

Berne. Fertile region. Valley (trade route).

Berlin. Fertile plain.
Stuttgart. Trade valley.
Munich. Trade valley.
Breslau. Fertile region. On river.
Warsaw. River. Fertile region.
Petrograd. Harbour and river.
Moscow. Fertile region. Between two large rivers.
Vienna. Fertile river valley used as trade route.
Pest. Where trade river flows into fertile plain.
Belgrade. Confluence of two rivers. Important military position.
Bukharest. Central position in fertile plain.
Sofia. Junction of two valleys. Mountain fastness.
Constantinople. Commanding Bosphorus. Harbour.
Athens. Ancient stronghold. Harbour.
Scutari. Very fertile. On lake (fishing?).
Cettinje. Mountain fastness.
Naples. Fertile bay. Good harbour. Health resort.
Rome. On river. Stronghold.
Turin. River. Where trade route enters fertile plain.
Milan. Central position in fertile plain.
Venice. Head of Adriatic, and at mouth of trade river. Lagoon harbour.
Lisbon. River and harbour.
Madrid. On commanding position near long and wide river. Fertile.
Copenhagen. On island commanding The Sound. Thus military and trading centre.
Christiania. River and harbour. Fertile valley.
Stockholm. Harbour. Fertile region.
Cairo. Mouth of river. Near fertile delta.
Aden. Trade route. Military position commanding both straits and interior.

Calcutta. River. Fertile delta with many harbours.
Madras. River. Military position.
Bombay. Harbour.
Colombo. Outlet from interior. Harbour.
Timbuktu. (Where desert trade route joins river most northerly point.) Oasis.

Sydney. Harbour Brisbane. Harbour Adelaide. Harbour Wellington. Harbour Dunedin. Harbour	Apparently just where the exploring navigator happened to strike the coast, which is full of harbours quite as good and even better.

Perth (W.A.). Harbour in fertile region (two rivers).
Hobart. Sheltered harbour (island in front of coast).
Cape Town. Harbour and military position.
Bloemfontein. River. Fertile plain.
Pretoria. Native trade centre. River.
Durban. Harbour.
Pekin. Fertile plain. Between two great rivers.
Seoul. Near harbour. Only large river from interior.
Tokio. Harbour.
Kioto. On lake surrounded by hills. (?Fertility.)
Sparta. Military position.
Thebes. Fertile plain. River. Military position.
Amphipolis. Harbour. Outlet for gold trade.
Tegea. Fertile plain.
Kimberley. Mines.
Brighton. Health resort.

Corinth. Sybaris.	Isthmus on trade route.

Carthage. Harbour. Military position.

Nineveh. Babylon.	Trade route (river). Fertile compared to desert.

Mycenae. Harbour. Military position. Fertile region.

STAGE 2. ARRANGING.

I.	Trade Route:—Paris, Stuttgart, Munich, Pretoria, Corinth, Sybaris.	6
II.	Harbours:—Bombay, Sydney, Brisbane, Adelaide, Wellington, Hobart, Dunedin, Durban, Tokio.	9
III.	Fertility[1]:—Berlin, Scutari, Tegea, Kimberley, Kioto (?).	5
IV.	Military Position:—Edinburgh, Cettinje.	2
V.	Central Position:—Brussels.	1
VI.	Health Resort:—Brighton.	1
		24
I and II:—	London, Dublin, Amsterdam, Petrograd, Constantinople, Venice, Lisbon, Colombo, Seoul, Amphipolis.	10
I and III:—	Berne, Breslau, Warsaw, Moscow, Vienna, Pest, Turin, Madrid, Cairo, Timbuktu, Bloemfontein, Pekin, Nineveh, Babylon.	14
I and IV:—	Sofia, Rome, Copenhagen, Aden, Madras, Sparta.	6
II and III:—	Stockholm, Perth (W.A.)	2
II and IV:—	Athens, Cape Town, Carthage.	3
III and V:—	Bukharest, Milan.	2
		37
I, II and III:—	Christiania, Calcutta.	2
I, III and IV:—	Belgrade, Thebes.	2
II, III and IV:—	Mycenae.	1
II, III and VI:—	Naples.	1
		6

[1] This is meant to include all natural resources and riches of the land, as mines, etc.

Stage 3. Inferences.

1. There are six main reasons for the situation of towns: trade routes, harbours, fertility, military position, central position, health.

2. Most towns are built with a view to two of the above reasons, except Australian towns, springing up merely because they happened first to give shelter to the exploring navigator.

3. There is little or no evidence of the element of chance, except in so far as harbours were apparently chosen indiscriminately on a coast rich in them.

Stage 4. Tentative Hypothesis.

All towns are situated either on trade routes, or on harbours, or in fertile regions, or in positions of military or naval importance, or in central positions convenient for exercising surveillance over a district, or in a particularly bracing spot for the purpose of recreating health; but generally towns are founded with a view to two or more of these functions.

Stage 5. Testing.

Manchester.	Explained by	III and V	surveillance over smaller towns.
Leeds.	,,	III and V	
Sheffield.	,,	III, (? V).	
Orléans.	,,	III, I.	
New York.	,,	II, I.	
Quebec.	,,	II, I.	
Port Elizabeth.	,,	II, I, (? III).	
Washington.	,,	V, II, I, (III ?).	
New Orleans.	,,	I, III.	

Chicago.	Explained by	I.
Prague.	,,	I, IV, V, (III?).
Larissa.	,,	III, V.
Salonika.	,,	I, II.
Smyrna.	,,	I, II, III, IV, V.
Kiev.	,,	I, V, (III?).
Königsberg.	,,	II, I, IV.
Riga.	,,	I, II, III, IV, V, VI.
Sevastopol.	,,	II, III, IV, VI.
Adrianople.	,,	IV, I, III.
Klausenburg.	,,	V, III.
Quito.	,,	III (mines), IV.
La Paz.	,,	IV, III (mines).
Panama.	,,	I.
Monte Video.	,,	II, IV.
Rio de Janeiro.	,,	II, V.
Santa Cruz.	,,	II, (III?).
Valparaiso.	,,	V (as port to Santiago), II.
Irkutsk.	,,	II, V, (IV?), (III?).
Blackpool.	,,	VI.
Nice.	,,	VI.
Spa.	,,	VI.

BUT

Jerusalem.	Though partly IV, III, V, yet partly because of religious interest.
Bury St Edmunds.	Solely because of abbey.
Ely.	Though partly IV, V, III, II, yet largely because of cathedral.
Cambridge.	Though partly IV, I, V, yet largely from educational interest.

Stage 6. Emending.

Thus the hypothesis falls through, or at least has to be emended. Thus we finally arrive at

Stage 7. Final Hypothesis.

All towns are situated either on trade routes, or harbours, or in fertile regions, or positions of military or naval importance, or in central positions convenient for exercising surveillance over a district, or in a particularly bracing spot, or at a locality of peculiar religious or other such interest or importance; but generally towns are founded with a view to at least two of these functions.

II.

Problem. What are the facts which determine the markings and colours of freshwater fish?

Evidence. Let us examine the markings of the following fish, and try to see the use of them :—

(*a*) The pike. Coloured dark green with shading on the back, light green and white underneath. He swims chiefly in mid water, and eats small fish, living both on the bottom and on the surface. His markings render him almost invisible from above or below.

(*b*) The trout lives often in clear streams and his spotted skin thus enables him to be almost invisible to his great enemy, man, against the gravel bottom.

(*c*) The roach lives chiefly on the bottom, and is coloured either dark green, brown, or black according to the locality, and white underneath. His big enemy the pike nearly always attacks from above; and it is from here that he is most invisible.

(*d*) The perch lives in streams with sandy bottoms, against piles and other such things. His brown and black striped back, while he is white underneath, renders him almost invisible to the small fish that form his prey.

(*e*) The dace lives either on the bottom or the surface; is coloured black or dark green accordingly on the back, and is a bright silvery colour underneath. His enemies, the pike and the perch, both attack from below him when he is on the surface, but his colour protects him well.

(I know I am liable to err here owing to my limited knowledge of the habits of fish, and total ignorance even of the existence of some small species.)

Classification. Most freshwater fish are similar to one of the species described above. Then we may classify as follows; (i) Fish which take the colour of their surroundings to capture their prey. (ii) Those which do so to escape from their enemies. We now frame our hypothesis:—

Hypothesis. Freshwater fish have their colour influenced by their surroundings and habits with a view to (i) escape from their enemies; (ii) catching their prey.

Testing. We now try to prove this by seeing how the habits and colour of other fish fit it.

(1) Bream is a bottom-feeding fish, subject to attacks from pike. It is therefore dark-coloured.

(2) Tench and carp are rather similar. They live on the bottom and are therefore dark-coloured, to protect them from the pike.

(3) Bleak is a surface fish with habits and markings similar to the dace.

(4) Gudgeon lives on gravel or muddy bottom and is more or less muddy coloured with spots, according to the locality.

Thus, none of these fish being contrary to the hypothesis, this hypothesis is so far correct.

Among the fish I have omitted to mention are:—chub, rudd, char, loach, minnow, grayling and barbel.

QUESTIONS

A.

(1) Give six examples of the way in which the mind interprets impressions presented to it by the senses.

(2) Give three examples of sense-impressions misinterpreted by the mind.

(3) Expand the statement that thoughts are judgments about sense-impressions.

(4) Illustrate the part played by experience in the interpretation of sense-impressions.

(5) What is the relation of science to our sense-impressions?

(6) Illustrate the difference between formal logic and scientific method.

B.

(1) What is the relation between the meaning of a word to us and our past experience?

(2) How do we learn to use words more accurately?

(3) Why is it important to eliminate our own peculiar notions as to the meanings of words?

(4) What kinds of words are most difficult to define, and why?

(5) What is meant by a logical definition?

(6) What is the value of the power to define correctly?

(7) Is it possible to define the following?

- (*a*) Julius Caesar.
- (*b*) Dogs.
- (*c*) Water.
- (*d*) Wheat.
- (*e*) Latin.
- (*f*) British Museum.
- (*g*) Being.

Give your reasons in all cases. If a thing cannot be defined, how can it be made known to others by means of language?

(8) What is a synonym? Give examples.

(9) What is the value of precision in the use of language? Give some reasons why such precision is difficult.

(10) State in your own words the virtues and the defects of language as a means of expressing thought.

(11) Give some reasons why it is difficult to impart truth to others by means of language.

C.

(1) Illustrate the difference between deduction and induction.

(2) What are the essential parts of a piece of inductive reasoning?

(3) State any problem, and indicate the steps by which you would solve it by induction.

(4) Illustrate by examples the danger of hasty generalization.

(5) What is meant by a working hypothesis?

(6) What ought our attitude to be towards a hypothesis?

(7) What qualities are required in a scientific worker?

(8) What exactly is meant by an experiment?

(9) In testing a hypothesis by experimentation what precaution should be observed?

(10) What is meant by evidence? Illustrate by examples the various kinds of evidence that present themselves in the solution of problems.

(11) What should be our attitude towards testimony which cannot be tested by experimentation?

(12) How should we estimate the probability of a piece of testimony of the kind mentioned in question 11?

(13) Illustrate from everyday life the weighing of evidence and the estimating of probabilities.

(14) Why is classification an important part of scientific work?

(15) Give examples of (*a*) correct and (*b*) incorrect classification.

(16) Give a rough classification of the sciences. Why is it impossible to classify them with perfect accuracy?

(17) Why are new sciences constantly arising?

(18) What is meant by a syllogism?

(19) What is the main principle of syllogistic reasoning?

(20) What are the essential parts of a syllogism?

(21) State the main rules of the syllogism.

(22) Why is it unwise to follow blindly these rules?

(23) Why has deductive logic fallen into disfavour during the last two centuries or so?

(24) Explain how syllogisms can be illustrated by combinations of circles.

(25) What is meant by analogy? Show how apt it is to influence our everyday reasoning.

(26) Explain what is meant by a fallacy, and describe the most common types of fallacy.

(27) Express as formal syllogisms the following arguments. Which arguments are fallacious, and why?

(*a*) It will rain to-morrow, because the moon has a halo.

(*b*) There must be pepper in this soup, it is so hot.

(*c*) The doctor's motor is outside *A*'s house. Somebody must be ill there.

(*d*) This liquid is acid. It turns blue litmus red.

(*e*) I must use *ut* in turning this sentence into Latin, as it expresses purpose.

(*f*) Richard the First was a good king, because he fought well.

(*g*) Why do you sigh? You have not lost a fortune.

(*h*) She drinks strong tea. Her nerves must be weak.

(*i*) X must be ill, as he has not written for three days.

(*j*) You ought to wear thicker clothes, for it is very cold.

(*k*) You cannot be really well, for you do not eat proper food.

(*l*) The Prime Minister is wrong; *The Times* says so.

(*m*) This body will not fall, for its centre of gravity is below the point of support.

(*n*) But Brutus says he was ambitious,
And Brutus is an honourable man.

(*o*) This figure has three sides; therefore its angles are equal to two right angles.

(*p*) John is a bad boy, for he was given only 30 per cent. for his French this week.

(*q*) Look at that crowd. There must have been an accident.

(28) What processes of thought ought one to go through before being convinced of the truth of the following pieces of information?

(*a*) The Greeks defeated the Persians at Salamis in the year 480 B.C.

(*b*) Pekin is the capital of China.

(*c*) Bubonic plague is spread by the fleas of infected rats.

(*d*) The formula of sulphuric acid is H_2SO_4.

(*e*) True synonyms do not exist.

(*f*) *Ut* and the subjunctive in Latin often express consequence.

(*g*) Common salt easily dissolves in water, chalk does not.

(*h*) The centre of gravity of a sphere is its centre.

(*i*) If a triangle has three equal sides it also has three equal angles.

(*j*) "To quickly write" is not good English.

(29) Describe the way in which the means of preventing malaria was discovered.

(30) Describe the experiments which proved that yellow fever is carried from man to man by *Stegomyia*.

(**31**) Outline the means you would adopt to solve the following problems.

(*a*) At what sort of points in his story does Virgil, in the *Aeneid*, use similes?

(*b*) What has been the effect upon history of the invention of new weapons?

(*c*) What are the best conditions for the cultivation of roses?

(*d*) What are the advantages of brown bread and white bread respectively?

(*e*) Does there appear to be any connection between industrial changes and political movements?

(*f*) What is the difference between the Latin words *frustra* and *nequiquam?*

(*g*) What causes dew?

(*h*) How can a cut cheese be kept from going mouldy?

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